CABLE BALANCE

CONTENTS

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers, contractors and other interested parties with technical information for use in the design and construction of REA borrowers telephone systems. It is written to provide an understanding of cable unbalances and their relationship to telephone system noise. Techniques for measurement of the various types of unbalance will also be discussed.

1.2 Capacitance (shunt) unbalance can be a major factor contributing to excessive noise in a telephone system. Precise measurement is expensive and time consuming and should be done only when there is strong indication that the cable may not meet applicable specifications.

1.3 Resistance (series) unbalance can be a contributing factor to excessive noise in a telephone system. Measurements of resistance unbalance should be made during noise isolation procedures on idle cable pairs.

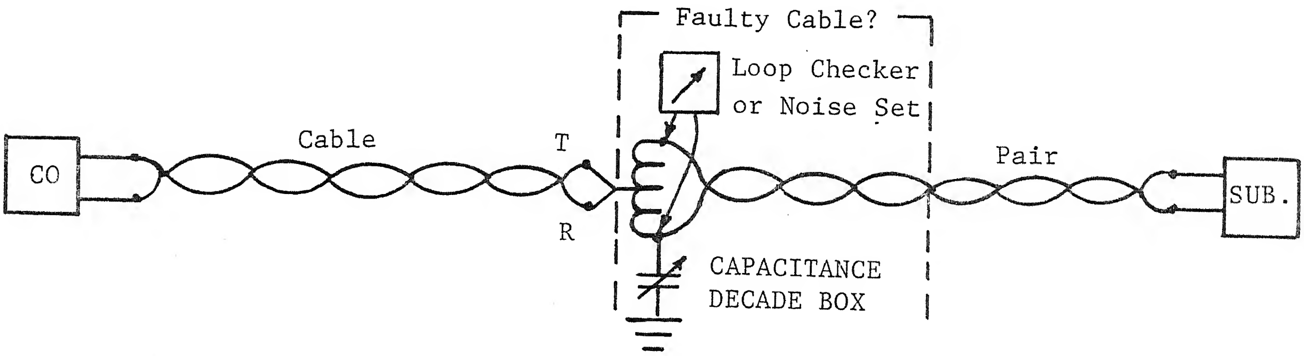
1.4 Investigation of the IEEE Standard 455-1976 method for measurement of longitudinal balance indicates it may be used for precise measurement of both capacitance and resistance unbalance in cable. Equipment for this test is less expensive than that required for direct measurement of capacitance unbalance. A discussion of this technique is discussed in Paragraph 4.

2. CAPACITANCE UNBALANCE

2.1 There are some procedures that can be followed during noise isolation tests to provide meaningful information. While results are not precise enough to prove the cable does not conform to specification, they will establish that; capacitance unbalance is a factor at the point of measurement, the side of the circuit that is unbalanced (T or R) and a broad indication of the magnitude.

2.11 When a noise problem has been isolated to a single section of cable, it is desirable to determine if a capacitance unbalance is the major factor. This may be easily proven with a capacitance decade box having 0.001 and 0.0001 microfarad steps.

2.12 With the isolation box connected to the cable for measurement, in the direction of the suspected unbalanced cable, connect the capacitance decade between the tip conductor and ground, as shown in Figure 1. Adjust the 0.001 and 0.0001 microfarad steps for lowest circuit noise.



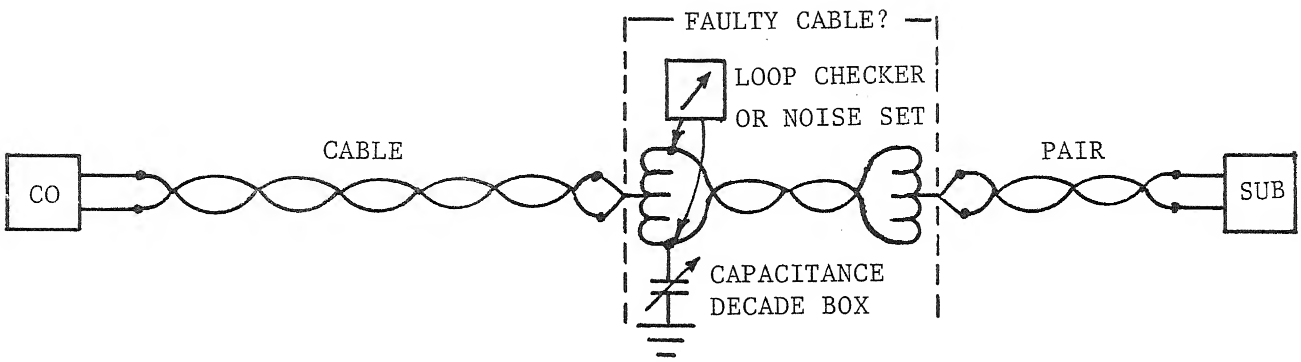
TEST TO DETERMINE IF CAPACITY UNBALANCE IS A NOISE FACTOR

FIGURE 1

2.13 If there is no improvement in the circuit noise, connect the capacitance decade box between the ring conductor and ground, and adjust the 0.001 and 0.0001 steps for lowest circuit noise. If circuit noise improves to less than 20 dBrnc and/or the balance to 60 dB or greater, the presence of capacitance unbalance is confirmed.

2.14 When circuit noise can be reduced only slightly, the unbalance may be due to resistance unbalance. For discussion of resistance unbalance, see Paragraph 3.

2.2 Results can be more precise and meaningful when two isolation sets are utilized. Connect an isolation set at each end of the suspected unbalanced section, as shown in Figure 2. Connect a capacitance decade box between the tip conductor and ground. While measuring circuit noise, adjust the 0.001 and 0.0001 microfarad steps for lowest circuit noise.



APPROXIMATE MEASUREMENT OF CAPACITY UNBALANCE

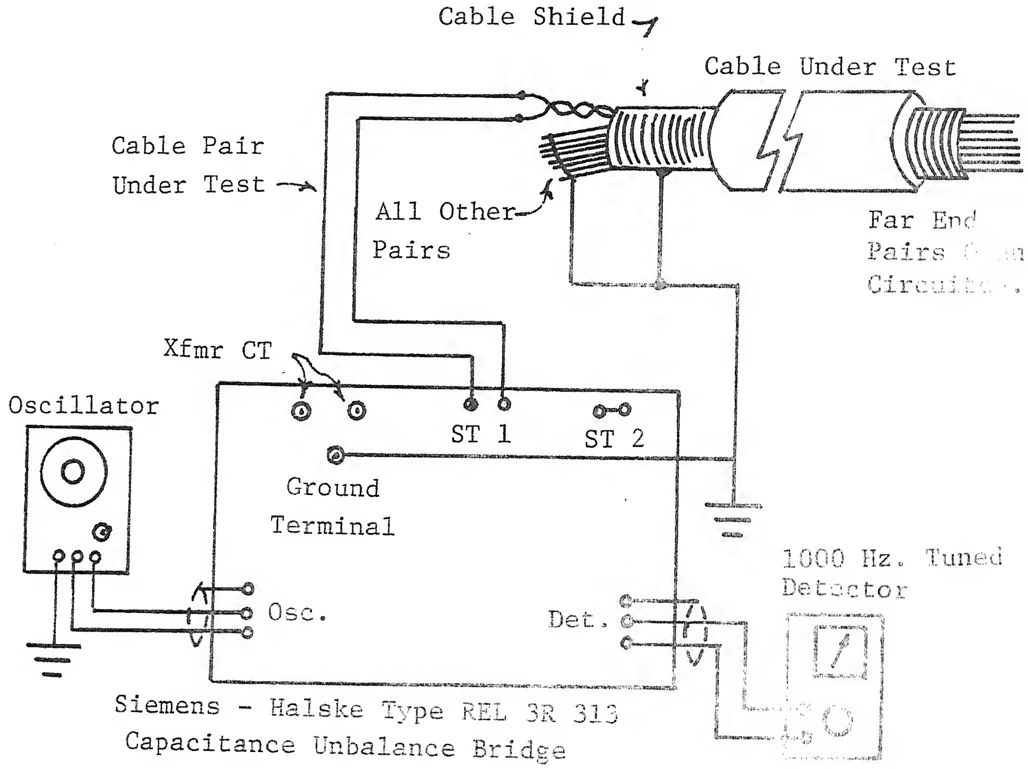
FIGURE 2

2.21 If the circuit noise does not improve, reconnect the capacitance decade box between the ring conductor and ground and, while measuring circuit noise, adjust the 0.001 and 0.0001 microfarad steps for lowest circuit noise. If the circuit noise improves to less than 20 dBrnc and/or the balance to 60 dB or greater, the presence of capacitance unbalance is confirmed. When measured in this manner and dividing the capacitance value of the decade steps by the length of the cable in kilofeet, the result will be approximately the capacitance unbalance of the cable in picofarads per kilofoot. Since the null of minimum circuit noise is quite broad, the result is not accurate enough to determine if the cable meets specifications.

2.22 When circuit noise can be reduced only slightly, the unbalance may be due to resistance unbalance. For a discussion of resistance unbalance, see Paragraph 3.

2.3 When there are indications that the cable does not meet the capacitance unbalance requirements, precise measurement of this parameter should be made as discussed below. Cable specifications establish capacitance unbalance objectives in either of two parameters, capacitance unbalance to shield or capacitance unbalance to ground.

2.31 <u>Capacitance Unbalance to Ground:</u> The capacitance unbalance to ground is a measure of the direct unbalance to the shield and all other conductors of the cable. Measurement of capacitance unbalance to ground is accomplished as shown in Figure 3 using a Siemens-Halske Type REL 3R313 Capacitance Unbalance Bridge or its equivalent.



MEASUREMENT OF PAIR-TO-GROUND CAPACITANCE UNBALANCE

FIGURE 3

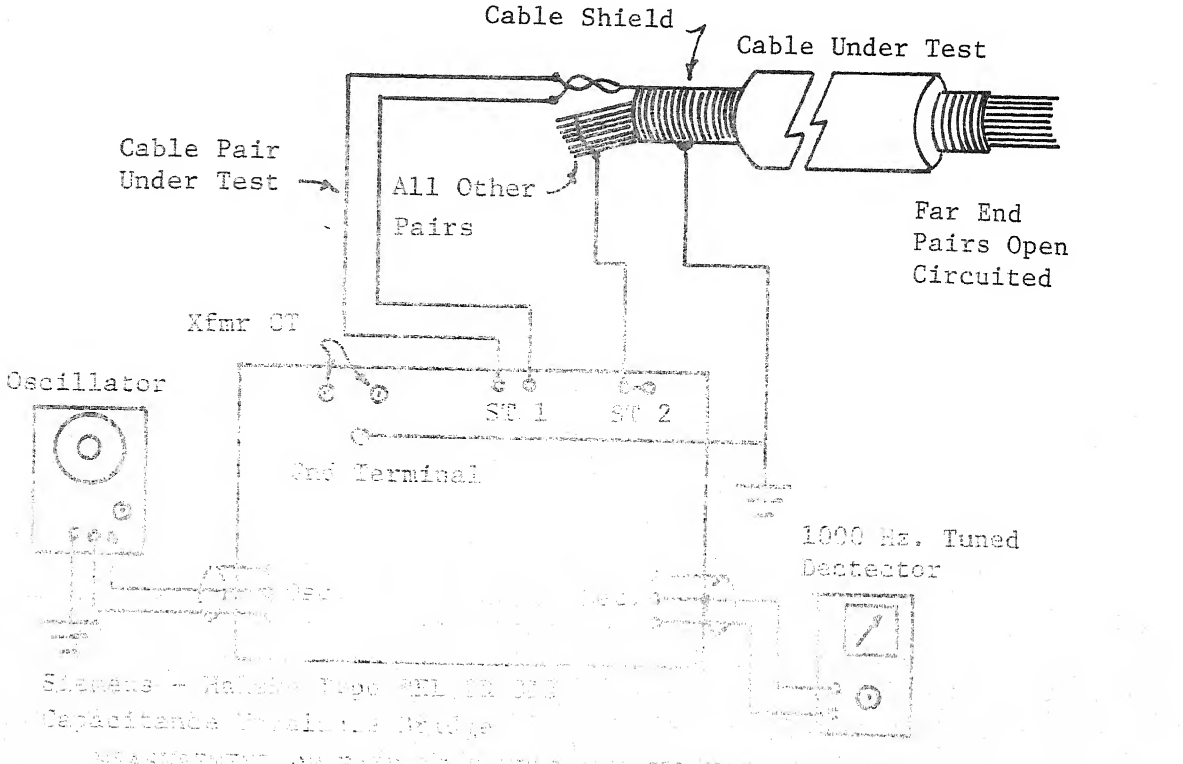
2.311 First, calibrate the bridge with the function switch set to [illegible] and all other controls set to zero. The bridge is balanced by $K_1 e_1$ and phase trimmers. Test leads should be included in the [illegible].

2.312 All pairs not being tested should be bunched and connected to [illegible] cable shield and the bridge ground terminal. The bridge ground terminal should be connected to an external ground. When testing cable in the field, which contains working lines, the working pairs are [illegible] grounded at the office and therefore may be left working and not [illegible] with the nonworking pairs.

2.313 The cable pair to be tested is connected to terminals ST-1 of the bridge.

2.314 Measurement is completed by setting the step capacitor and varying the main differential capacitor and phase trimmer, as necessary. As the detector meter indicator drops, add gain to the detector. Continue this procedure until the null point is reached. At the null point, any movement of the main differential capacitor in either direction will produce a higher meter indicator reading. Capacitance unbalance in picofarads is the algebraic sum of the step and differential capacitors. This may be converted to picofarads per kilofoot by dividing the value in picofarads by the cable length in kilofeet.

2.32 <u>Capacitance Unbalance to Shield</u>: Capacitance unbalance to shield is a measure of the direct unbalance to the shield with the influence from all other pairs removed by a guard circuit. There is a direct relationship between capacitance unbalance to shield and telephone circuit noise. Measurement of capacitance unbalance to shield is accomplished as shown in Figure 4 using a Siemens-Halske Type REL 3R313 Capacitance Unbalance Bridge or its equivalent.



2.321 The bridge is first calibrated in the same manner as described in Paragraph 2.311 above.

2.322 All pairs not being tested should be bunched and connected to the ST-2 terminals of the bridge. The cable shield is connected to the bridge ground terminal and the bridge ground terminal is connected to an external ground. When testing cable in the field, which contains working lines, the working pairs should be removed from service and connected to terminals ST-2 for accurate results.

2.324 The cable pair to be tested is connected to terminals ST-1 of the bridge.

2.325 Measurement is completed in the same manner as described in Paragraph 2.314 above. Capacitance unbalance to shield in picofarads per kilofoot may be obtained by dividing the recorded results of this test by the length of the cable in kilofeet.

3. RESISTANCE UNBALANCE

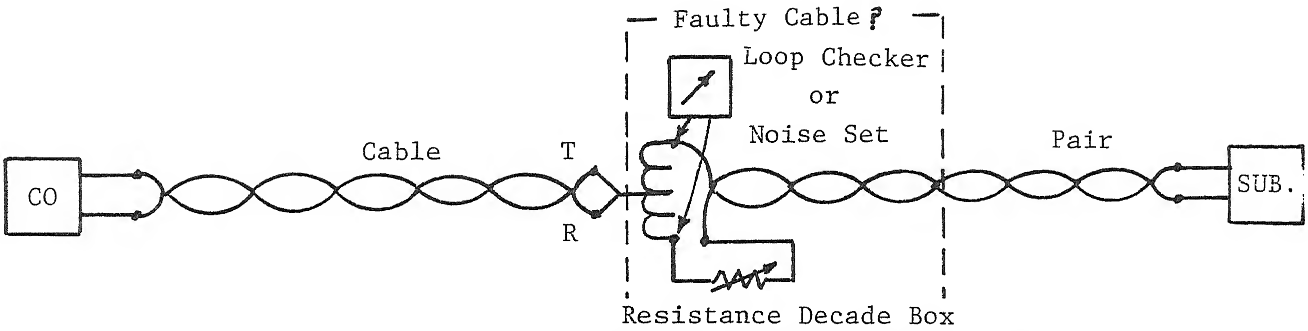
3.1 While measurement of the net overall resistance unbalance should be made at the subscriber end of the circuit for reference purposes, it does not provide a reliable clue as to its effect on noise. This is because the location of the resistance unbalance in relation to a low impedance to ground is a controlling factor relative to its contribution to circuit noise.

3.2 As discussed in Paragraph 8.2 of TE¢CM 451 a resistance unbalance in this area will result in the highest conversion to circuit noise. Resistance unbalance located near the end of the circuit may be an insignificant contributor to the overall circuit noise.

3.3 Even though the precise measurement of resistance unbalance is not possible during isolation tests on working pairs, there are some procedures that will provide some meaningful information. These procedures will establish if resistance unbalance is a factor at the point of measurement, the side of the circuit that is unbalanced and an approximate indication of the magnitude.

3.31 When a noise problem has been isolated to a single section of cable, it is sometimes desirable to determine if resistance unbalance is a major factor. If an idle cable pair is being tested, this will be found through direct measurement. Where a working pair is being tested, direct measurement is not possible. Meaningful data can be obtained by using a resistance decade box having 1.0 and 0.1 ohm steps.

3.32 With the isolation box connected to the cable for measurement in the direction of the suspected unbalanced cable, connect the resistance decade in series with the tip conductor as shown in Figure 5. The shortest possible test leads should be used between the isolation set and the decade box. Adjust the 1.0 and 0.1 ohm steps for lowest circuit noise.



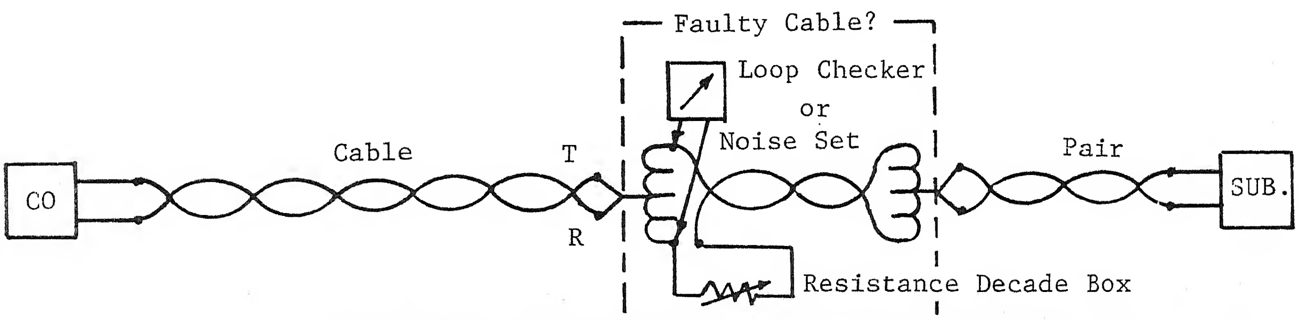
TEST TO DETERMINE IF RESISTANCE UNBALANCE IS A NOISE FACTOR

FIGURE 5

3.33 If the circuit noise does not improve, reconnect the resistance decade box in series with the ring conductor and adjust the 1.0 and 0.1 ohm steps for lowest circuit noise. If the circuit noise improves to less than 20 dBrnc and/or the balance to 60 dB or greater, resistance unbalance is a major factor at the point of measurement.

3.34 Should the circuit noise improve only slightly, the resistance unbalance is probably acting in tandem with capacitance unbalance. Where no change in circuit noise occurs, the resistance unbalance at this location is not contributing to the noise problem. Capacitance unbalance is discussed in Paragraph 2.

3.4 Results can be more precise and meaningful when two isolation sets are utilized. Connect an isolation set at each end of the suspected unbalance section, as shown in Figure 2. Connect a resistance decade in series with the tip conductor as shown in Figure 6. The shortest possible test leads should be used between the isolation set and the decade box. Adjust the 1.0 and 0.1 ohm steps for lowest circuit noise.



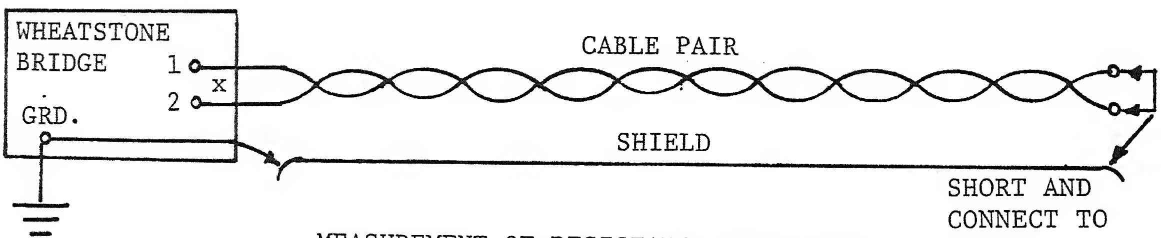
APPROXIMATE MEASUREMENT OF RESISTANCE UNBALANCE

FIGURE 6

3.41 If the circuit noise does not improve, reconnect the resistance decade in series with the ring conductor and while measuring circuit noise, adjust the 1.0 and 0.1 ohm steps for lowest circuit noise. If the circuit noise improves to less than 20 dBrnc and/or the balance to 60 dB or greater, resistance unbalance is a major factor at the point of measurement.

3.42 Should the circuit noise improve only slightly, the resistance unbalance is probably acting in tandem with capacitance unbalance. Where no change in circuit noise occurs, the resistance unbalance at this location is not contributing to the noise problem. Capacitance unbalance is discussed in Paragraph 2.

3.5 Resistance unbalance should be measured section by section during noise isolation measurements. Connect the cable pair to the wheatstone bridge as shown in Figure 7.



MEASUREMENT OF RESISTANCE UNBALANCE

FIGURE 7

3.51 Bridge Settings

Res-Var-Mur switch on Var.
Multiply by switch on $\frac{1}{1}$

R.V.M.-Ga-Hil switch on RVM

3.52 Procedure: Adjust the 1, 10 and 100 ohm switches, as required, to obtain zero on meter. If this cannot be done, reverse x1 and x2 to the cable pair and try again. Unbalance is read directly from the sum of the 100, 10 and 1 ohm dials.

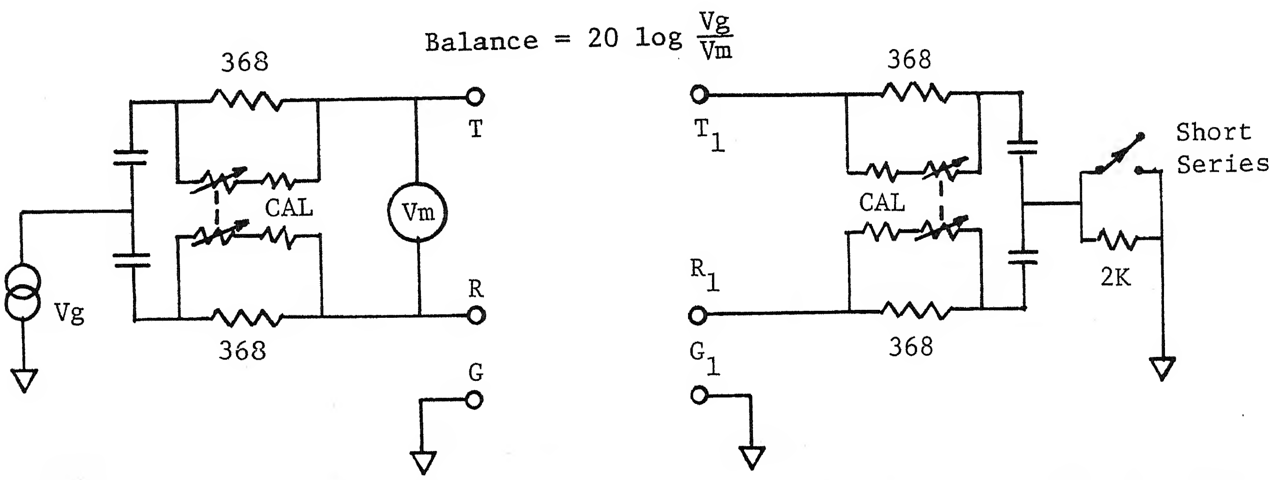
4. LONGITUDINAL BALANCE

4.1 IEEE Standard 455-1976, "IEEE Standard Test Procedure for Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band", describes a method for measuring the shunt and series balance of components used in telephone systems. The procedure was originally developed to measure components such as line relays, transmission bridges, and similar devices.

4.11 Cable is also a component used in telephone systems. The IEEE procedure can be used for measurement of series and shunt longitudinal balances in cable. Investigation indicates that when tests are made with the one-port method, the results in dB may be converted to precise values of capacitance unbalance to ground in picofarads per kilofoot and resistance unbalance per total length. This is because capacitance unbalance is the major factor of cable shunt unbalances and resistance unbalance is the major factor of cable series unbalances. Insulation resistance unbalance is normally much too high to be a factor in cable shunt balance.

4.12 The standard test procedure is capable of both one-port (unterminated) and two-port (terminated) measurements. As noted in Paragraph 4.11 above, there is a direct relation between results of one-port measurements and cable unbalances. The two-port method probably gives a better representation of how the cable will perform in the field under the same operating environment as provided for the test. Results, however, cannot be related directly to values of capacitance and resistance unbalance.

4.13 A portable, battery-powered balance test set can be developed to facilitate testing longitudinal balance of cable in the field. The cost of this equipment would be far less than that for capacitance unbalance bridges. A simplified schematic of this test set is shown in Figure 8. The longitudinal measuring device should have a balance at least 15 dB higher than the highest balance to be measured.



CABLE LONGITUDINAL BALANCE TEST SET
FIGURE 8

4.14 If balance of installed cable is to be measured the balance test set should be frequency selective to eliminate effects of induced longitudinal voltages.

4.2 The formula shown below may be used for computation of, anticipated results using the one-port method of longitudinal balance measurements for various lengths and gauges of cable.

$$\text{dB Bal.} = 20 \log \frac{Z_1 + Z_2 + R + \frac{Z_1 Z_2}{R} + \frac{1}{Z_3}(RZ_1 + RZ_2 + 2Z_1Z_2)}{Z_1 - Z_2}$$

4.21 Where for shunt unbalance:
Z_1 = Complex impedance one conductor to ground
Z_2 = Complex impedance other conductor to ground
Z_3 = Complex inpedance between the two conductors
R = Internal resistance of test set (368Ω)

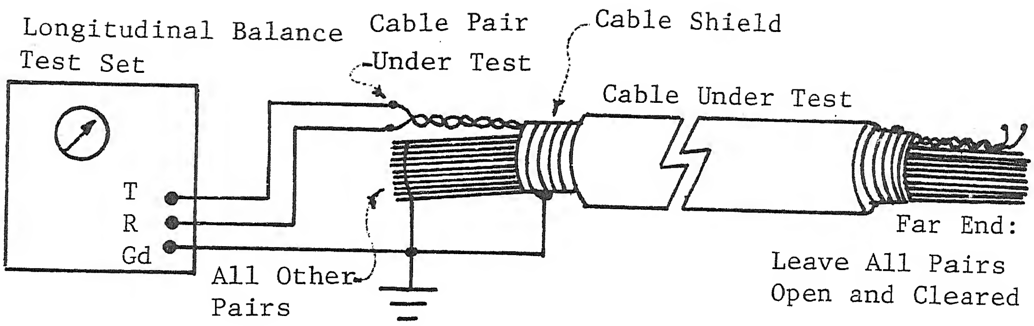
4.22 Where for series unbalance:
Z_1 = Resistance of one conductor
Z_2 = Resistance of other conductor
Z_3 = Impedance between two conductors (for series measurements Z_3 may be ignored)
R = Internal resistance of test set (368Ω)

4.3 Charts 1 through 3 show the anticipated balance values for lengths and gauges of cable that will most frequently be measured in plant. This is based on the premise that noise will most frequently occur on longer loaded cable of "D" or "H" loading with 22 or 24 gauge cable. These charts are convenient for converting results of shunt longitudinal balance measurements in dB to capacitance unbalance-to-ground in picofarads per kilofoot and series longitudinal balance in dB to resistance unbalance for total length.

4.4 Measurement of longitudinal balance in both the series and shunt mode using the one-port method is quite simple. This method of measurement is illustrated in Figure 9. The first step is to calibrate the test set for highest balance (between 100 and 120 dB).

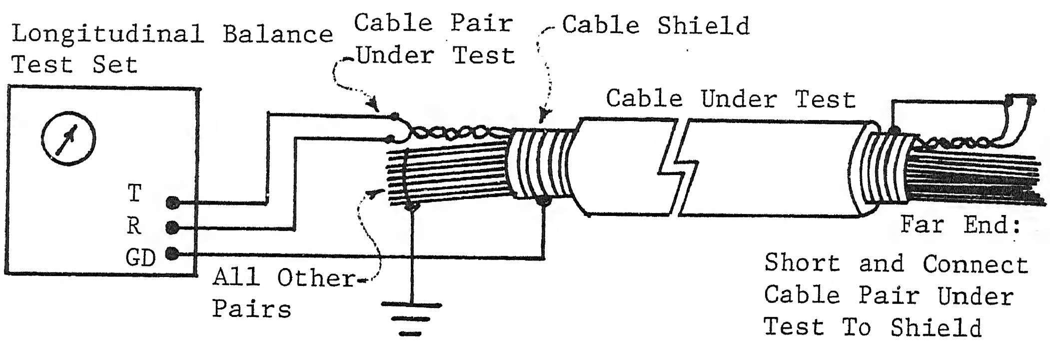
4.41 At the measuring end, the cable pair is connected to the tip and ring of the test set and the shield is connected to the ground terminal of the test set. The loading coil should not be connected to the length being tested. All nonworking pairs in the cable should be shorted together and connected to the shield and ground terminal. Working pairs are grounded through the office and thus are effectively grounded.

4.42 Shunt unbalance is measured with both the pair to be measured and idle pairs open circuited at the far end. Shunt circuit balance in dB is read on the test set meter and recorded. With this value and the length of the cable known the unbalance in picofarads per mile may now be found in the charts.



SHUNT UNBALANCE

STEP ONE



SERIES UNBALANCE

STEP TWO

MEASUREMENT OF CABLE LONGITUDINAL BALANCE

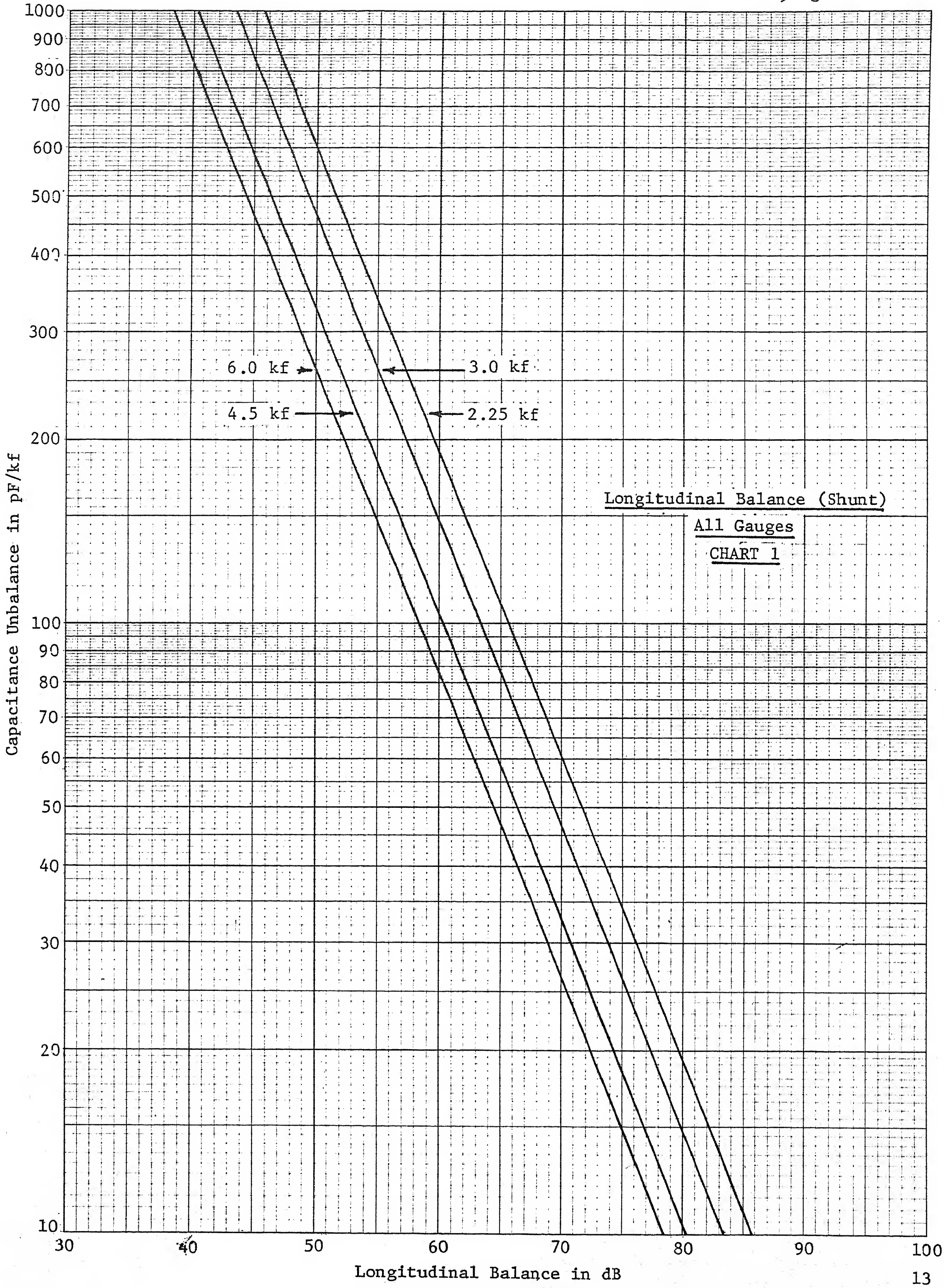
FIGURE 9

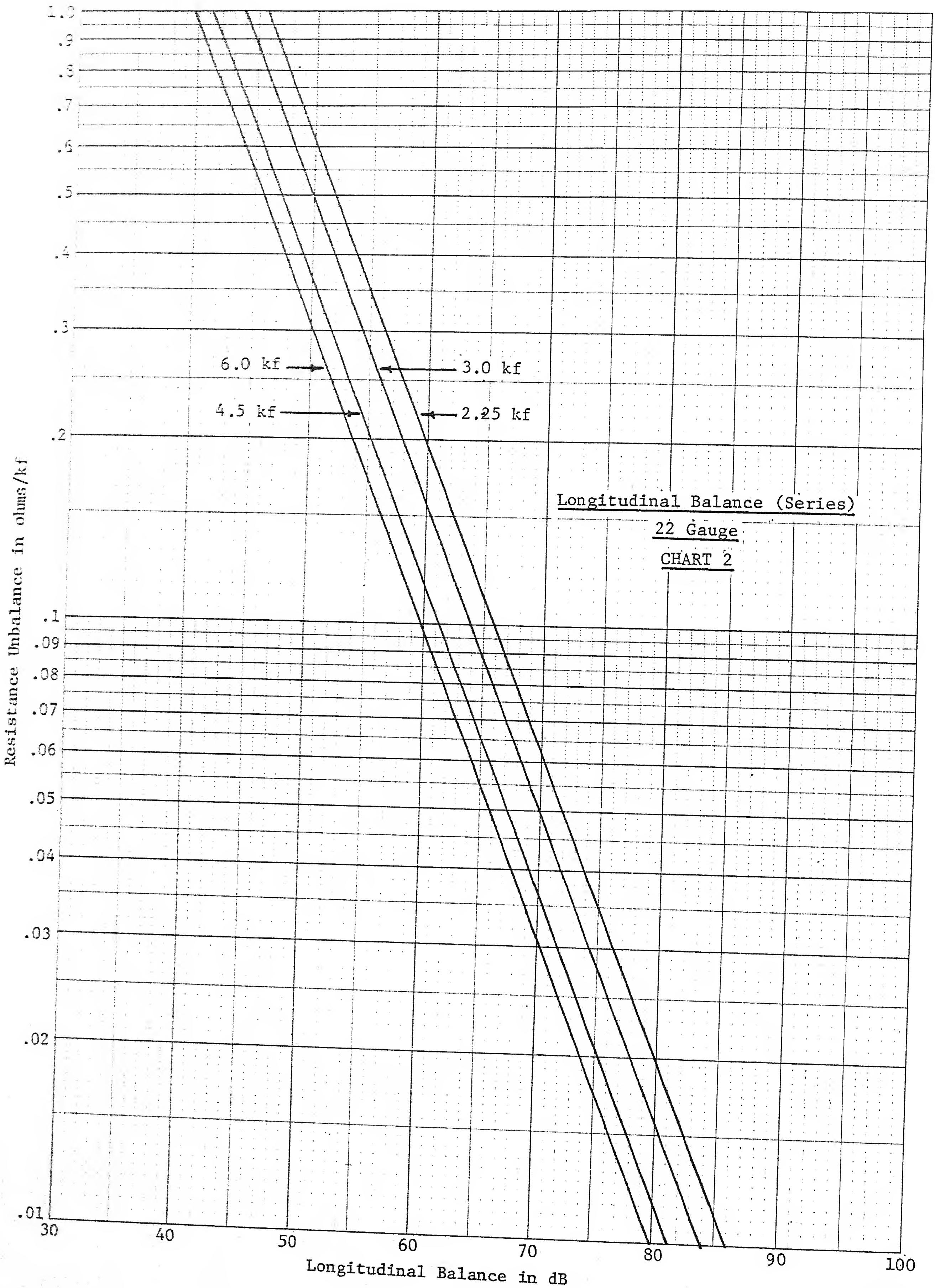
4.43 Series unbalance is measured with the pair to be measured shorted and connected to the cable shield at the far end. Idle pairs should still be open circuited at the far end although the state of all other pairs has negligible influence on the results of series unbalance measurements. Series circuit balance in dB is read on the test set meter and recorded. With this value, and the length and gauge of the cable known, the unbalance in total ohms may be found in the charts.

4.5 Should it be desirable to determine which side of the pair has the lowest value of capacitance or resistance, a decade box may be used.

4.51 Connect a capacitance decade between the tip conductor and ground at the point of measurement. Add capacitance in 100 picofarad increments and note if balance improves. If it does not, reconnect decade between the ring conductor and ground. Again add capacitance in 100 picofarad increments noting if balance improves. The lowest capacitance to ground will be with the conductor to which the decade box is connected when longitudinal balance improves.

4.52 Connect a resistance decade box in series with the tip conductor at the point of measurement. Add resistance in one ohm steps and note if balance improves. If it does not, reconnect decade in series with the ring conductor. Again, add resistance in one ohm steps noting if balance improves. The lowest resistance will exist on the conductor to which the decade box is connected when longitudinal balance improves.


Longitudinal Balance (Shunt)
All Gauges
CHART 1
6.0 kf
4.5 kf
3.0 kf
2.25 kf
Capacitance Unbalance in pF/kf
Longitudinal Balance in dB
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
30
40
50
60
70
80
90
100



Longitudinal Balance (Series)
22 Gauge
CHART 2
6.0 kf
4.5 kf
3.0 kf
2.25 kf
Resistance Unbalance in ohms/kf
Longitudinal Balance in dB
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
.09
.08
.07
.06
.05
.04
.03
.02
.01
30
40
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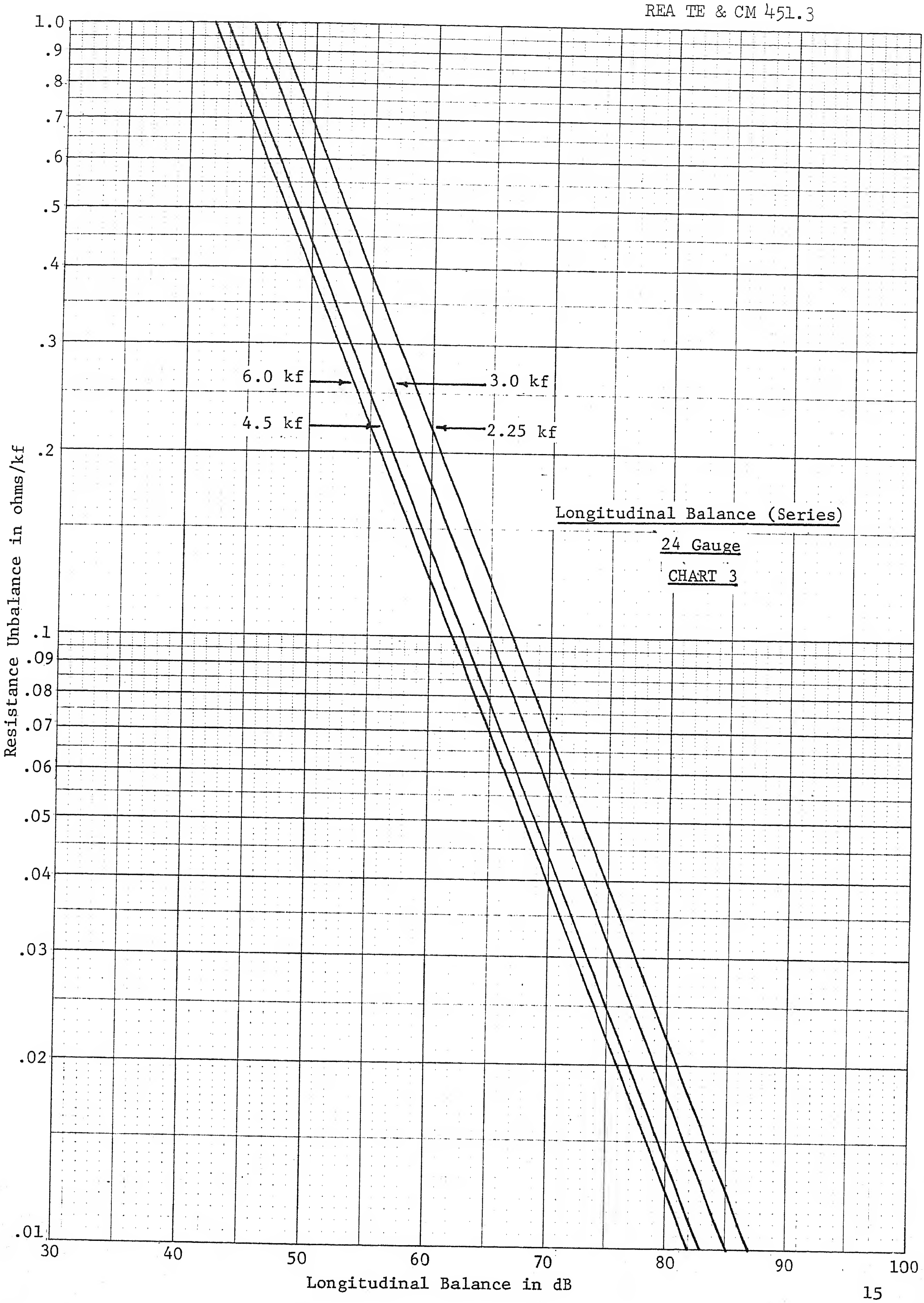
1.0
.9
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.04
.03
.02
.01
Resistance Unbalance in ohms/kf
6.0 kf
4.5 kf
3.0 kf
2.25 kf
Longitudinal Balance (Series)
24 Gauge
CHART 3
30
40
50
60
70
80
90
100
Longitudinal Balance in dB